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UNITED STATES
DEPARTMENT OF AGRICULTURE
In cooperation with the Illinois Agricultural Experiment Station and the Illinois State Department of Agriculture.
DEPARTMENT CIRCULAR 273
Washington, D. C. June, 1923

FLAG SMUT OF WHEAT.

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DISCOVERY AND PREVALENCE.

FLAG SMUT OF WHEAT was discovered in some of the wheat fields in Madison County, Ill., in May, 1919. This disease had not previously been known to occur in the United States, although its presence in other countries throughout the world had been known for many years. It had been reported in Australia 50 years earlier and is found widely distributed in that country. It is also present in Japan, India, China, and South Africa. In some parts of Australia the losses from flag smut are reported to be very heavy, reducing the yield from 5 to nearly 70 per cent annually in some cases.

Since 1919 flag smut has been found in five other contiguous counties in Illinois, in three adjacent counties in Missouri near St. Louis, and in several counties in northwestern Missouri and northeastern Kansas near Kansas City. The infested area in Illinois in 1922 was about 50 miles long and from 5 to 15 miles wide. The disease has not caused much loss in the infested area, usually not more than 1 per cent of the plants being infected, except in small parts of some fields, where the infection has been much heavier. The indications are that it may become a serious disease unless adequate control measures are put into effect.

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[1] A paper prepared by the writers of this circular and published as Bulletin 242 of the Illinois Agricultural Experiment Station gives in detail the results of the experiments conducted on flag smut. Anyone desiring more extensive information on the subject may obtain a copy of the Illinois bulletin on sending a request to the Director of the Illinois Agricultural Experiment Station, Urbana, Ill.

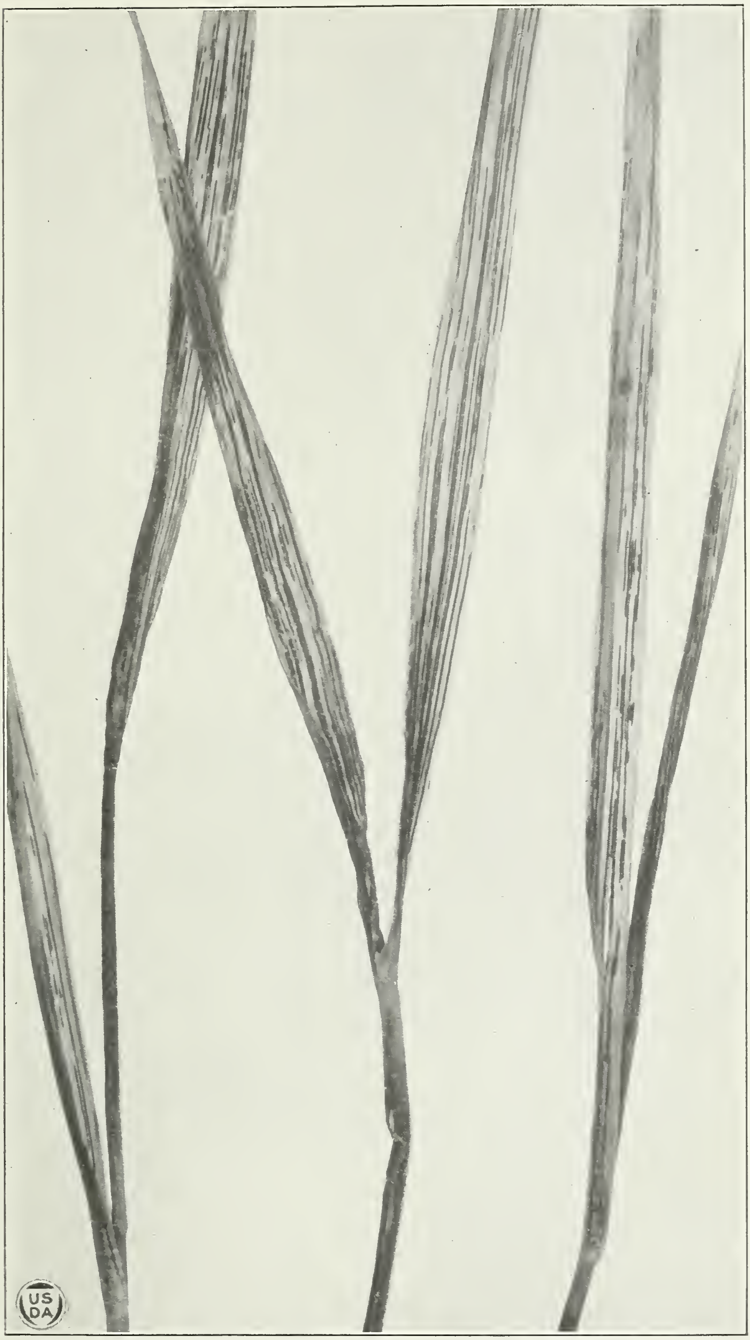
SYMPTOMS OF FLAG SMUT.

Flag smut appears as black stripes running lengthwise in the leaf blades and sheaths of the wheat plant (Pl. I). In the early stages the stripes are somewhat lighter than the green color of the normal leaf, but later they become lead colored and finally black. These stripes (Pl. II, *A*) are filled with dark-colored spores (Pl. II, *B*), which are produced by a fungus or small parasitic plant known as *Urocystis tritici* Kcke. The black stripes may be seen in the leaves, especially the upper leaves, before the jointing of the plants has taken place. They also may often be seen in the stems. Infected plants are usually more or less dwarfed. The leaves and sheaths become twisted in some cases and the infected culms rarely head and produce seed. Sometimes normal heads are developed on smutted plants, but usually the entire plant is affected and no sound heads are produced. Where heads appear on infected culms the black stripes may be present on the glumes at the base of the head and usually are present on the culm just below the head. The flag smut of wheat is different from the stem smut of rye, being caused by a different, though related, organism. The fungus causing flag smut of wheat will not infect rye; neither will the fungus causing stem smut of rye infect wheat.

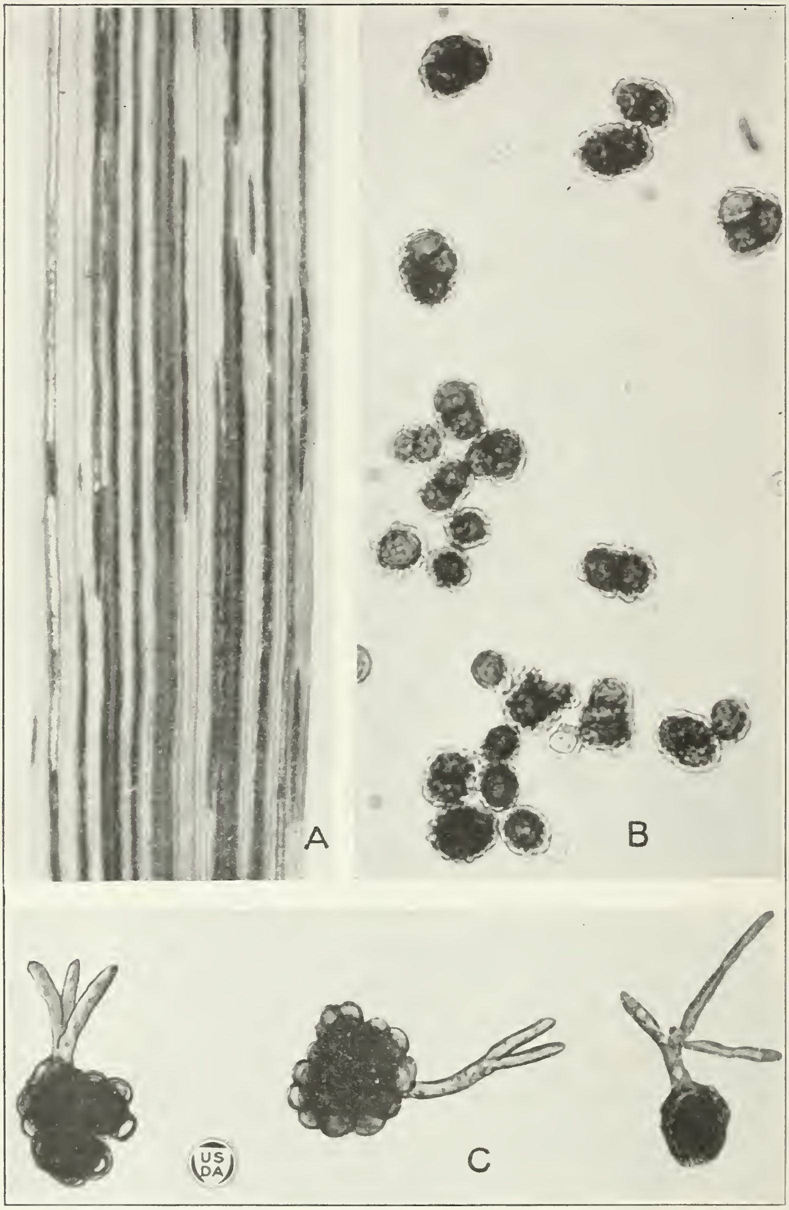
The small dark-colored smut spores, or seeds, of the fungus which are formed in the spring in the wheat plant may become attached to the wheat kernel in threshing or may fall and become mixed with the soil. They may be blown by the wind or carried by water or by other means, such as threshing machines or other farm implements and by man and animals, for considerable distances from the infected plants. When smutty wheat is sown or when clean wheat is sown in infested soil, the young wheat seedlings immediately after germination are penetrated by minute threadlike tubes or hyphæ which arise from the flag-smut spores (Pl. II, *C*). These hyphæ, which are so small that they can scarcely be seen with the aid of a microscope, grow up through the tissues of the young wheat plant, from which they obtain food. They live in the plant over winter and in the spring begin to produce the dark-colored spores which are seen as long black stripes in the wheat plant.

CONTROL MEASURES.

Flag smut may be held in check and reduced in quantity by judicious quarantine measures, seed treatment, crop rotation, and other sanitary measures and by growing resistant varieties of wheat. The development of the disease is also influenced by soil and weather conditions at the time the wheat is sown. Quarantine and farm sanitation measures have been studied in cooperation with the Illinois State Department of Agriculture, and numerous experiments on varietal resistance have been under way in cooperation with the Illinois Agricultural Experiment Station. Quarantine and sanitary measures put into effect by the Illinois State Department of Agriculture include the regulation of shipments of infected grain and straw, the disinfection of farm machinery, etc., when leaving the infested area, the burning of straw, and the treatment of seed grain.



PORTIONS OF WHEAT PLANTS, SHOWING THE BLACK STRIPES CAUSED BY FLAG SMUT RUNNING LENGTHWISE IN THE LEAF BLADES AND SHEATHS.



FLAG SMUT OF WHEAT.

A.—Portion of a wheat leaf (enlarged four times) showing the black stripes caused by flag smut. Note that some of these stripes have ruptured. *B*.—Spores of *Urocystis tritici* Keke. Photomicrograph showing the spore balls as they appear under the microscope (× 300). *C*.—Germinating spores of *Urocystis tritici* Keke. (After McAlpine.) Note the promycelium bearing two to three secondary spores or sporidia at the apex (× 600).

SEED TREATMENT.

Experiments have shown that the spores of flag smut carried on seed wheat can be destroyed by treating the seed with copper sulphate or with formaldehyde. It has been found that the usual strengths and methods of application of these chemicals employed in connection with the control of other wheat diseases are satisfactory for destroying the flag-smut spores. Submerging the seed for 10 minutes in a solution of 1 pound of copper sulphate to 5 gallons of water and then for 5 minutes in limewater containing 1 pound of lime to 10 gallons of water will destroy the spores on the seed. It was also found that spores on the seed were destroyed by soaking the seed for 10 minutes in a solution of 1 pint of formaldehyde to 40 gallons of water and then covering it for 4 hours, after which it was spread out to dry before sowing. Copper-carbonate dust, which has been used successfully in Australia and in the Pacific Coast States for controlling bunt in wheat, has given good results in the one year in which it has been used to control flag smut where the spores are carried on the seed. Copper-carbonate dust has the advantages of being easiest to apply and of not causing seed injury. Seed treated with this dust is more easily handled than when treated with a solution, because the grain does not have to be dried. This dust is thoroughly mixed with the seed at the rate of 2 ounces to a bushel. This mixing can be done by shoveling the grain over on a floor or revolving it in a barrel churn or other contrivance which causes the kernels to be covered with a thin film of the dust.[2]

None of these seed treatments, however, prevented infection of the plant by spores that were present in the soil. Flag-smut spores will live in the soil from harvest until seeding time and have even been found to live over winter in parts of smutted plants buried in the soil. Seed treatment therefore can not be depended upon to control the disease when the wheat is sown on land which is infested.

CROP ROTATION.

Wheat sown in the infested area in fields where flag smut has not occurred for one or more years has been found to be less infected by smut than if sown in fields where the disease occurred the preceding year. Because of the fact that the smut spores easily survive from harvest to seeding time and are present to infect fall-sown wheat, it is especially important that fields producing wheat infested with flag smut be sown to other crops the following year. Records obtained in surveys made in the area affected by flag smut indicate that crop rotation will be of some value in controlling the disease, as fields on which crops other than wheat were grown previously were found to have less flag smut than fields which had been cropped to wheat for a number of years and in which flag smut was known to occur. These records further indicate that the continuous growing of susceptible wheat on infested land may result in an increase of the disease, as has been found to be the case in Australia.

It has been determined that the smut spores can survive in the soil and infect a wheat crop even though the land has not produced wheat for one year. It is evident, therefore, that at least two years should intervene between wheat crops on the same land unless immune varieties are sown, and it is possible that three or more years must pass before the land is entirely free from the spores. As this disease does not affect crops other than wheat, choice may be exercised as to what crops should be grown in the rotation. Any material that may contain flag-smut spores, such as straw, manure, or a straw mulch on potatoes, when applied to the land may serve as a source of infection. For the best results infested crop residues and manures should not be returned to the soil, but if this practice is deemed desirable in the light of the dangers involved the safest place in the rotation to apply such material is on the wheat stubble.

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[2] Copper carbonate dust irritates the nose and throat, and it is advisable to use some form of respirator to prevent inhaling it.

DATE OF SEEDING.

Experiments have shown that early-sown wheat will contain more smut in the resulting crop than wheat sown later in the fall. It has also been shown that it is not practicable to control smut by late sowing, as it is necessary to delay seeding until the middle of November, or even later, in order entirely to prevent infection. Yields from wheat sown at this late date were very low. There was very little difference in the percentage of smut in different sowings made sufficiently early to insure a good crop. The lack of infection in late-sown wheat was apparently due to the soil temperatures, which were too low at the late dates to permit spore germination and infection. For this same reason wheat sown in the spring has not been infected, but spring wheats are not adapted to the section where flag smut is found.

VARIETIES RESISTANT TO FLAG SMUT.

The use of varieties resistant to flag smut offers the most promising means of controlling the disease. In the experiments begun in the fall of 1919 and carried on since that time in the flag-smut area, a number of varieties have been found which are highly resistant to or possibly even immune from the disease. The seed with which these experiments were made was heavily covered with flag-smut spores in each case before it was sown, in order that the plants might be subjected to the maximum chance for infection. The varieties shown in Table 1 have remained free from flag smut in these experiments for two or three years, and it is believed that they will furnish a basis for combating the disease by the use of immune or highly resistant varieties.

TABLE 1.—*Varieties of wheat which remained free from flag smut when grown from smutted seed at Granite City, Ill., for two or three years in the 3-year period from 1920 to 1922, inclusive.*

Variety.	C. I. No.	Years tested.
Hard red winter:		
Kanred	5146	2
Kanred (seed from Ill. Agr. Exp. Station)	5146	2
P-1068	5880	2
Turkey (Illinois 12-41; seed from Ill. Agr. Exp. Station)		2
Soft red winter:		
Beechwood (seed from Mo. Agr. Exp. Station)		2
Fulcaster—		
Eversole	3011	2
Marvelous	2980	2
Stoner	2980	2
Soft red winter—Continued.		
Grandprize (St. Louis Grand Prize)	5627	3
Imperial Amber	3447	3
Penquite (Velvet Chaff)	3068	2
Red May (Early Harvest)	4852	2
Red Rock	5597	3
Shepherd	6163	3
Squareheads Master	3283	3
Ulta No. 834[1]	5747	2

[1] The variety recorded here as Ulta No. 834 is beardless, with red glabrous chaff and red kernels. The name Ulta is usually applied to a variety of the Turkey type.

HARD RED WINTER WHEATS.

Three strains of hard red winter wheat have been found free from infection in these experiments. These are Kanred, P–1068, and Turkey (Illinois 12–41). Other strains of hard red winter wheat, notably Illinois 10–110, Malakof, and P–1066, have been very slightly infected; so slightly, in fact, that infection may be due to slight mixtures of susceptible varieties in the seed of these strains. These results indicate that the hard red winter wheats of the Turkey or Crimean type are highly resistant to flag smut. Unfortunately, however, the hard red winter wheats are not well adapted to this section of Illinois. The soft red winter wheats have been grown almost exclusively and are more satisfactory to the farmers. The hard wheats have a weak straw, are bearded, and do not succeed well on much of the land where flag smut is found. The quality of grain from this class of wheat also is not of the best when grown under the conditions found in this section, as there is a tendency toward "yellow berry," which is undesirable from the market standpoint. A considerable acreage of these wheats was sown by the farmers in 1921 and 1922, but much dissatisfaction was reported, especially on the heavier types of soil. On the lighter soils the results were fairly satisfactory in 1922.

SOFT RED WINTER WHEATS.

All of the soft red winter wheats listed in Table 1 probably are adapted to growing in the present flag-smut area with the exception of Squareheads Master and Ulta. Both bearded and beardless varieties are included in this list. The beardless varieties, in addition to the two mentioned above, are Beechwood, Early Harvest, and Shepherd. Unfortunately, there is no commercial supply of seed of these varieties, as they represent strains developed in connection with wheat-breeding operations. Shepherd wheat is being increased as rapidly as possible, however, and a thorough test of it will soon be made. It is known to be immune from the rosette, which also is present in this locality. Early Harvest also has been found immune from rosette, but Beechwood and Ulta have not been included in the rosette-resistance experiments.

The other wheats of the soft red winter class listed in Table 1 are bearded. These include Eversole, Marvelous or Stoner (synonyms for the Fulcaster variety), Imperial Amber, Penquite, and Red Rock. Seed of Stoner (Marvelous) and of Red Rock is available in commercial quantities. These wheats also are not affected by rosette. Seed of Eversole, Imperial Amber, and Penquite is not available for general sowing. Eversole is immune from rosette, but the other two have not been tested.

Several other wheats have been only slightly infected by flag smut when grown from smutted seed. In some cases the slight infection may be due to unavoidable mixtures, such as are frequently found in strains of wheat. The important varieties showing high resistance—that is, varieties averaging less than 1 per cent of smutted plants in two or three years' tests—may be grouped as follows:

(1) Bearded wheats with smooth glabrous white chaff, purple straw, and red kernels:
    Bearded Purplestraw, Dietz, Fulcaster, Lancaster, Mammoth Red, and Nigger.

(2) Similar to group 1, but having yellow straw:
    Gipsy, Reliable, and Valley.

(3) Bearded wheats having smooth glabrous red chaff and red kernels:
Red Rock (C. I. 5976) and Miller's Pride.
(4) Beardless wheats with smooth glabrous red chaff and red kernels:
Michigan Wonder, Red May, and Poole.

All of the wheats listed in these four groups are of the soft red winter class and are good or fairly good for milling purposes. The Fulcaster variety is widely grown, and large stocks of fairly pure seed are available in Illinois.

WHEAT GROWING IN THE FLAG-SMUT AREA.

The principal soft red winter varieties now grown by farmers in the flag-smut area are shown in Table 2. All of these are more or less susceptible to the disease. The Harvest Queen (also known as Salzer's Prizetaker or Red Cross), which is most susceptible, has almost disappeared from the worst infested section in Illinois, as the farmers have realized that it is very susceptible to flag smut and also to the rosette. The Red Wave and Fultz varieties still are widely grown.

TABLE 2.—*Wheat varieties grown commercially in the infested area in Illinois, all of which are susceptible to flag smut and should not be sown in this area.*

Variety.	Number of selections.	Average smut infection (per cent).	Number of years tested.
Flint (May)	Average of two selections	20.4	1
Fultz	Average of several selections	9.5	2
Harvest Queen (Salzer's Prizetaker, Red Cross)	do	23.77	3
Jones Fife	Average of two selections	6.97	2
Red Wave	Average of several selections	4.27	2

Conditions in the American Bottoms, the lowland section of Madison County, Ill., were very favorable for the development of flag smut in 1919, the year in which it was found. Harvest Queen, known locally as Salzer's Prizetaker, was one of the most widely grown varieties. Other somewhat less susceptible varieties made up a large part of the remaining area in wheat. Wheat is grown extensively in Madison and St. Clair Counties. According to census data wheat in 1919 occupied 38.2 per cent of the improved land on the farms in Madison County and 41.7 per cent of that in St. Clair County. Wheat occupied 45 and 47 per cent, respectively, of the acreage of all land in crops. Wheat frequently follows wheat in the rotation and wheat fields are close together (in fact, practically continuous) throughout the entire area. The methods of culture, therefore, as well as the varieties used, furnish conditions very favorable to the development and spread of flag smut and other diseases and to their accumulation in the soil.

Inasmuch as wheat is such an important crop in the area specified in this circular, it is not practicable to discontinue growing it in order to combat flag smut. The most effective means of control appears to be the use of resistant varieties, especially those that have been shown to be immune in the experiments conducted in the area now reported. It is possible that by the use of these varieties, kept free from susceptible mixtures, the disease may be entirely eradicated.